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MBA PROFESSIONAL REPORT

Analysis of the Costs and Benefits of the USMC Light Armored Vehicle Depot Maintenance (IROAN) Program

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                December 2006

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY (*Leave blank*)	**2. REPORT DATE** December 2006	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report	
4. TITLE AND SUBTITLE: Analysis of the Costs and Benefits of the USMC Light Armored Vehicle Depot Maintenance (IROAN) Program			**5. FUNDING NUMBERS**
6. AUTHOR John Ethan Smith			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this report are those of the author(s) and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE** A
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14. SUBJECT TERMS Cost-Benefit, Depot Maintenance, Light Armored Vehicles			**15. NUMBER OF PAGES** 55
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

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ANALYSIS OF THE COSTS AND BENEFITS OF THE USMC LIGHT ARMORED VEHICLE DEPOT MAINTENANCE (IROAN) PROGRAM

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The Inspect Repair Only As Necessary (IROAN) program is a depot level maintenance program designed to improve the operational availability of Light Armored Vehicles in the Marine Corps inventory. The policy for assigning vehicles to the IROAN program is based on age, mileage and operating hours, with the primary criteria being time since last IROAN cycle. A cost benefit analysis was conducted using historical readiness reporting to determine if the current policy is the most cost effective among reasonable alternatives. Research indicates that the LAV fleet is actually managed on an eight year cycle, with vehicles from the operating forces receiving depot maintenance more frequently. Indications are that the average time between depot maintenance for operating force vehicles is only slightly more frequent than the optimal timing of seven years. In the course of this research it became clear that the fragmented nature of USMC vehicle maintenance data makes performing these types of studies time-consuming and expensive. Consequently the difficulties in obtaining relevant data limit the quality of information available to support the Program Manager's decisions.

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I.   INTRODUCTION

A.   GENERAL DESCRIPTION

The past five years have seen the Marine Corps committed to operations around the world at a rate not seen for four decades. The leadership of the Marine Corps recognizes the demands that this has placed both on the service members and their equipment. The Marine Corps planned on its equipment being used at a certain rate with a maintenance and recapitalization plan built around those assumptions. Because the Marine Corps has exceeded those planned operational employment rates for the past 5 years, there have been challenges in maintaining the readiness of the equipment, and those challenges are likely to continue.

The Marine Corps is not alone in this situation. The Army, which has an even greater amount of equipment, is grappling with how to maintain the readiness of their equipment, whether it is bulking up maintenance processes or speeding up recapitalization. They have commissioned several studies to help them focus on which efforts are likely to generate the greatest benefit to the combat power of the Army (Peltz, 2005). One of these studies conducted by Rand Corporation delved deeply into the factors affecting the operational availability of M1 tanks. One of the major research questions was how to use statistical models of operational availability relationships to inform decisions about recapitalization (Peltz, 2005. xiv).

This study seeks to quantify the relationship between operational availability and the depot overhaul program the Marine Corps Light Armored Vehicles (LAVs). With a similar goal to the Rand study, the purpose is to provide the LAV Program Manager (PM LAV) a useful measure of the economic benefit of the current program. The PM may then make more appropriate decisions on the allocation of resources to ensure the highest possible level of support for the operating forces.

There is s suspicion within the LAV community that the IROAN program has not been cost effective. The impetus for this project came from then Program Manager LAV,

Colonel John Bryant, USMC (personal communication, April 2006). Unit costs for the IROAN program have soared over the past decade, and combined with the pressures created by increased operational tempo and reduced safety stock at the Depot, it became necessary to systematically evaluate the effectiveness of the program (Mullins, Adams, Sims, 2005). LAV Depot Maintenance is currently being reconsidered. The alternative to the current IROAN is Specified Overhaul and Return (SOAR), and it includes a significantly reduced Statement of Work, with the goal of reducing repair cycle time to 60 days and average unit cost to $200,000 (CWO3 Persely, personal communication, October 2006). This research project is independent of the restructuring of LAV Depot Maintenance, but is clearly relevant to the matters under consideration.

The IROAN process has been previously researched by Naval Postgraduate School students. In 2005, Michael Mullins, Troy Adams and Robert Simms analyzed the Depot's effectiveness in implementing Theory of Constraints into their processes. Ronald Wilson conducted a Cost Benefit Analysis of reducing the number of LAV depot maintenance sites form two to one in December of 2000. Both of these studies provide valuable insight into the Marine Corps' maintenance system. But they both focused on how to make the depot maintenance process more efficient or effective, vice attempting to measure the contribution of IROAN to vehicle readiness.

In general the approach that will be used in this project report will mirror Edith Stokey and Richard Zeckhauser's framework for analysis (Stokey & Zeckhauser, 5). Their approach was developed for the policy decision maker in the public sector and includes the following steps: 1) Establish the context, 2) Lay out the alternatives, 3) Predict the consequences, 4) Value the outcomes and 5) Make a decision. Since the goal of MBA Project is to provide better information to the Program Manager about the effectiveness of a program, the project will only pursue steps one through three and apply some example methods of valuing the outcomes.

II.   BACKGROUND

A.   FAMILY OF LIGHT ARMORED VEHICLES

1.   Program Origins

The U.S. Army and the Marine Corps identified a need for a light armored platform in the 1970's. Officially designated the Mobile Protected Weapons System, the acquisition program did not progress very far until 1979. The Iranian Hostage crisis highlighted to the Defense community the need for a rapidly deployable force with sufficient mobility and firepower to accomplish missions once it was deployed. Airborne forces were too light for the threat, and armored forces were too heavy to deploy quickly. Under these circumstances, Marine Major General Al Gray successfully was instrumental in convincing the administration and Congress to fund an off the shelf buy of approximately 700 light armored vehicles. The program was approved in 1980, and the first unit officially stood up in 1986 as the LAV Battalion. The name of the units changed several times as the Marine Corps developed employment doctrine, finally settling on Light Armored Reconnaissance Battalion in the early 1990's.[1]

2.   Description of Variants

Eight different variants of the Family of Light Armored Vehicles (FOLAV) have been purchased by the Marine Corps, seven of them still in service. The bulk of the 700 vehicles are LAV-25 variants. These vehicles have a hydraulically powered turret that is armed with a 25mm Bushmaster chain gun, a 7.62mm coaxially mounted machine gun, and a commander's 7.62mm machine gun. The crew consists of a commander, gunner, driver, and a three man scout team. A Light Armored Reconnaissance Battalion currently has 60 of these vehicles, with four of them in the HQ, and the remaining 56 evenly split

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[1] Michael Peznola, "Marine Light Armor 1980-1999 Operational Goals Tactical Results: A Study in the Dynamics of Change", Research Paper for the School of Advanced Warfighting, Marine Corps University, Quantico, Va.1999. Major Peznola's research paper is the best available source on the establishment of Light Armor in the Marine Corps.

among four LAR companies with 14 each. The companies normally have three platoons of four vehicles, and two LAV-25s in the HQ section. This vehicle carries out the bulk of the unit's missions. With their mix of firepower and manpower, they have proven very capable in accomplishing missions throughout the spectrum of conflict. Total inventory authorized within the Marine Corps is 407 (CWO3 Persely, personal communication October 2006).

Figure 1.   LAV-25

The LAV Anti-Tank (LAV-AT) is armed with an Emerson 901 turret capable of firing four TOW missiles before reloading. The turret was originally developed and utilized by the U.S. Army for use on the M113 APC chassis. The turret carries two Tube launched, Optically tracked, Wire guided (TOW) anti-tank missiles ready to fire. There are four LAV-ATs in each LAR Company, organized into a section led by a Staff Sergeant. They are typically employed in support of LAR platoons. They have a crew of four, a commander, gunner, driver, and loader. The total USMC inventory is 95 vehicles.

Figure 2.   **LAV Anti-Tank**

The LAV Mortar (LAV-M) is armed with an 81mm mortar mounted on a turntable. It can be fired from the vehicle, but it must be stationary and the hatches over the rear of the vehicle must be opened. There are two LAV-Ms per LAR Company and they are normally used to provide marks for Close Air Support, provide illumination and provide immediate suppression to support disengagement. The LAV-M has a crew of 6; driver, commander, gunner, assistant gunner, and two ammo men. There are 50 of these vehicles in the Marine Corps inventory

Figure 3.   **LAV Mortar**

The LAV Logistics variant (LAV-L) is a cargo variant. It is used by logistics and maintenance personnel to move supplies around the battlefield, and can be outfitted with a kit to transform it into an armored ambulance. There are three per LAR Company, with one typically employed as an ambulance, one for transporting supplies and ammunition

and the third for carrying tools and parts. Its crew of two is comprised of a driver and commander, and there are 16 in a battalion (four LAV-Ls in headquarters). The Marine Corps has 94 LAV-L vehicles.

Figure 4.   LAV Logistics

The LAV Command and Control Variant (LAV C2) provides robust communication capabilities. The vehicles provide four VHF, one HF, one UHF, and one SATCOM channel. Each LAR Company has one of these vehicles, and the battalion headquarters has four. The crew comprises a commander and driver, with seating stations for five personnel in the back. There are 50 LAV-C2s in inventory for the Marine Corps.

Figure 5.   LAV Command & Control

The LAV Recovery variant (LAV-R) is essentially a wrecker for the LAV. It has a 10,000 lb. extendable boom, a 60,000 lb. winch, an acetylene torch and an arc welder. The LAV-R has a crew of four; comprising driver, commander, boom operator, and

welder. There is one LAV-R per LAR Company, and the battalion HQ has two in its maintenance platoon. There are 45 units of this variant in the Marine Corps inventory.[2]

Figure 6.   LAV Recovery

The seventh variant still in the Marine Corps inventory is the Marine Electronic Warfare Support System (MEWSS). There are less than 15 of these vehicles in the inventory. They reside in the MEF's Radio Battalion as a signal intelligence and electronic warfare platform. The MEWSS vehicle has a crew of four; driver, commander, and two system operators. These vehicles are a part of the IROAN program, but due to their small numbers and their separation from the LAR Battalions in mission and sophistication of their equipment, they are managed by a different organization even though the system uses the same vehicle platform.

All variants have seen a great deal of use while in service with the Marine Corps. Different demands are placed on the various models due to the manner in which they are employed. The LAV-25, as stated before, is the backbone of the unit and is involved in almost every mission. When conducting reconnaissance operations, they frequently travel over rough terrain right up to the limits of the vehicles' capabilities. While conducting security operations the vehicles are usually stationary, but will still have to

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[2] There are multiple open sources on the internet that are available for information on LAVs. The HQMC factfile website at http://www.hqmc.usmc.mil/factfile.nsf is a good source as well as http://www.globalsecurity.org/military/systems/ground/index.html. Both of these sources were accessed in October 2006.

run their engines approximately $1/8^{th}$ of the time to maintain enough charge in the batteries to operate the turret systems and start the vehicle.

Figure 7.   MEWSS

The LAV C2 has very different demands placed upon it. Due to the large electrical demand of the communications system, this vehicle spends a lot of time idling to maintain charge on its batteries. Because it is a key part of the Command cell, and there is only one per company, it is used a lot during operations and in training. These vehicles usually have a lot of recorded operating hours.

The LAV-AT also has some peculiar characteristics. The turret system is notoriously unreliable, and because there are so few units in service within DOD, parts are very difficult to obtain. The complexity and fragility of the system forced some amphibious units not to take their LAV-ATs on deployment, either going without or substituting LAV-25s. This situation might skew the data pertaining to these vehicles.

3.   Distribution and Historical Employment

The Marine Corps has three active duty Light Armored Reconnaissance Battalions, and one reserve battalion. First LAR Battalion is based out of Camp Pendleton, CA and belongs to the First Marine Division. First LAR has four LAR Companies and a Headquarters and Support Company. First LAR Bn supports the 11, 13, and 15 Marine Expeditionary Units with platoon to company sized detachments. Second LAR Battalion is based in Camp Lejeune, NC under the command of the Second

Marine Division. Second LAR Bn also has four LAR companies and an H&S Company and they support 22, 24, and 26 MEU. Third LAR Battalion is based in 29 Palms, CA and belongs to the 1st Marine Division. Third LAR Bn has four LAR Companies, but only three companies' worth of vehicles. The fourth company of vehicles is in Okinawa as part of the Third Marine Divisions' Combined Assault Battalion. Third LAR Bn has one company on deployment to man the vehicles in Okinawa.

LAR Company Table of Equipment for Light Armored Vehicles
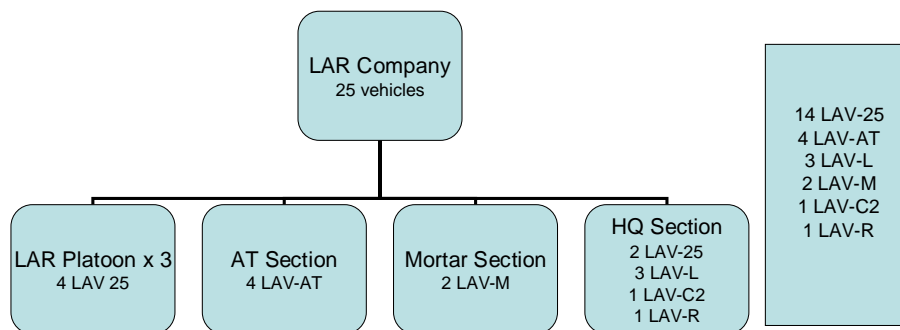
Figure 8:   **LAR Company from MCRP 5-12**

The reserve battalion is 4th LAR Battalion and they are a part of the 4th Marine Division (Reserves). Company A is located in Camp Pendleton, CA. Company B is in Fort Detrick, MD. Company C is in Toele, UT. Company D is in Quantico, VA. Additionally, the Marine Corps has pre-positioned reserve equipment in the Maritime Pre-positioned Squadrons (MPS) and placed a number of LAVs in training organizations. These vehicles represent what is called "out of stores". The "in stores" population consists of the Depot Maintenance Float Allowance (DMFA) and War Reserve Material Requirement (WRMR).

4. Maintenance Concept

Light Armored Vehicles are maintained using a three level system. Organizational maintenance capability in Light Armored Reconnaissance units is robust, meaning that organizational maintenance is equipped, manned, and trained to perform a large percentage of the total maintenance tasks. This capability comes at a cost of extensive tool sets, and approximately 80 LAV mechanics in each battalion.

The intermediate maintenance capability resides in the Force Service Support Group's Ordnance Maintenance Company (OMC). There is one OMC per Marine Expeditionary Force. This unit primarily conducts repairs on certain components of armored vehicles within the MEF. These items are referred to as "secondary repairables" or "secreps."

The third level of maintenance is the depot. There are two maintenance depots for the USMC LAVs; one in Albany, Georgia and the other Barstow, California. These two maintenance centers conduct major hull repairs and perform the IROAN process. The depots are resourced through working capital funds. This means that the depots are supported by a revolving fund which is replenished as that they are paid for the work that they perform by the operating forces "pay" for work using Operations and Maintenance funds. Since depot rates reflect full cost recovery, labor, materials, and overhead are all present in the Direct Labor Hour (DLH) rate that they charge for the year. The operating forces send vehicles to the depot based upon how much O&M they received for the given Fiscal Year. Typically, sophisticated models are used for programming and budgeting for depot maintenance, and the workload generally is close to the agreed upon amount between the operating forces and the maintenance centers.

B. IROAN PROCESS

1. Vehicle Process

After programming and budgeting are completed and the number of vehicles to go to depot has been determined, a Master Work Schedule is built to maintain a steady flow of vehicles in and out of the depot. Once a particular vehicle has a start window, the owning organization begins preparing the vehicle for shipment. This usually takes two

weeks, and entails the removal of certain equipment and multiple inspections. Equipment that is removed is referred to as SL-3 items, and it includes radios, tools and fire extinguishers. These items will be reinstalled on replacement vehicles that have gone through overhaul. The inspections are meant to streamline work at the depot, in that depot mechanics have a listing of known defects on a vehicle when it arrives.

Once the inspection and item removal tasks are completed, the vehicle is shipped to the depot and upon its arrival is received by the Fleet Support Division (FSD). FSD maintains the Depot Maintenance Float Allowance and stores the inbound LAVs awaiting IROAN. Normally vehicles will be held two to four weeks in FSD before and after completing IROAN.

During the IROAN process the vehicle is stripped of all components until only the hull remains. The hull is inspected for corrosion and fractures. Following the hull inspection, the vehicle is repainted, and components are replacing broken with good ones as necessary. Once completely reassembled, the vehicle is inspected and tested by the depot personnel. Deficiencies are corrected by the depot and the vehicle is transferred back to the Fleet Support Division. FSD preserves, packages, stores and then prepares the vehicle for shipment back to a using unit. "Analysis of Light Armored Vehicle Maintenance", an MBA Professional Report by Michael Mullins, Troy Adams and Robert Simms is available for a more detailed description and analysis of the IROAN Process.

Once the operating forces receive the overhauled vehicle, they must remount the SL-3 components and conduct receiving inspections. Again this usually takes a couple of weeks. Frequently bugs need to be worked out in the vehicle and small repairs made.

Overall the end-to-end repair process takes about 150 days. The Maintenance Centers have reduced their cycle time to 120 days (Mullins, 40), but this does not account for the organization's preparation time on both ends of the process, or for transportation to and from the depot. Normal shipping times are around 7 days; organizational preparation is about one week on either end. These activities add another month to the process, bringing the total to about 150 days. Normally there is a queue at the FSD

before the process and after the process, further increasing repair cycle time. However, current Operational Tempo and vehicle casualties have eliminated that queue. 150 days is currently a fair assessment of the true repair cycle time for the IROAN program. The Mullins, Adams and Simms Report (2005) goes into greater detail into the actual process at the Maintenance Centers.

C.   PROGRAM MANAGER

The Program Manager for the Light Armored Vehicles (PM LAV) is based in Warren, Michigan. A Marine Colonel holds the billet and is responsible for the life cycle management of the LAV fleet for the Marine Corps and to support the fleet of LAVs with the Saudi Arabian National Guard. PM LAV's organizational chart is useful to outline the myriad of tasks they are charged with accomplishing.

Business Management and Contracts divisions provide support to the project divisions by providing expertise in particular acquisition areas. LAV Upgrades/ International manages the three upgrade programs referenced in Figure 9, and supports the Saudi Arabian National Guard's fleet of LAVs. The LAV A2 program office manages the acquisition of the additional 120 LAVs that the Marine Corps needs to equip five new LAR Companies, as well as the upgrade program to get the legacy fleet to the same level of capability as the new vehicles(Persely, personal communication October 2006) .

Sustainment/Readiness is focused on the readiness of the vehicles in the operating forces. They support the fleet by maintaining contracts for parts, incorporating fleet recommended modifications, monitoring the performance of parts to identify components that could be replaced to improve readiness and managing the LAV IROAN program. Specifically, the PM holds the funding for the IROAN program, and determines what will be done in the process, and how many vehicles will go in a given year. This means that the PM has to fight for the funding in the PPBES process

Program
Manager

Operations

Business Management

Contracts

Sustainment/ Readiness

LAV Upgrades/Int'l

LAV A2

ITSS

SLEP Basic

LAV C2

SANG
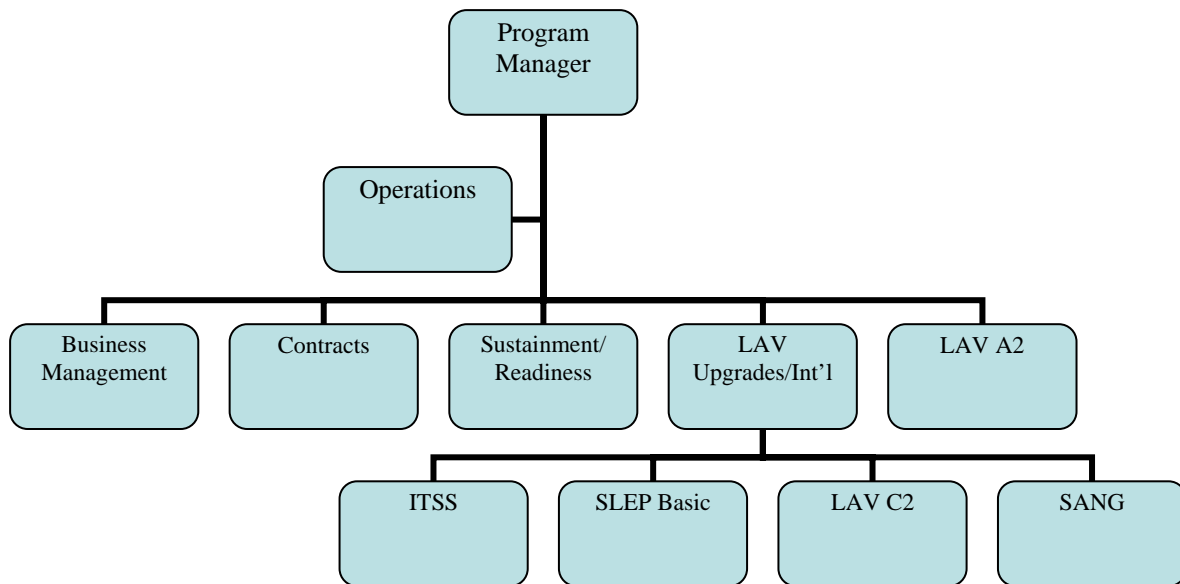
Figure 9: **PM LAV organizational structure from Colonel Bryant's Advanced Planning Brief to Industry April 2006**

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Overall, the PM has a mission to support the fleet of LAVs that the Marine Corps owns. The PM collects information through both formal and informal channels. Formally, there are two annual conferences within the LAV community that the Program Management Office will attend. The PM sponsors a maintenance conference to solicit input from the fleet which parts or processes are an issue, and this event is normally attended by battalion maintenance officers and maintenance chiefs as well as executive officers. The Light Armored Reconnaissance Operational Advisory Group meets annually and includes LAR Bn commanders. The primary mission of this group is to prioritize acquisition programs for the community, and justify their necessity. The results provide input into the Marine Corps' programming and budgeting processes. The PM is a non-voting member of this group, but he is central to providing much needed acquisition and programming information to the group. These meetings also provide an opportunity for the Program Manager to obtain feedback from his primary customers.

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III.   METHODOLOGY

A.   APPROACH

In simple terms, this project seeks to quantify the readiness benefits of the IROAN program and compare these benefits to the costs.   The traditional approach attempts to forecast future revenue streams or cost savings expected from alternate decisions and compare them to expected costs.   In this case the historic costs of the IROAN process are well documented.   Forecasting cost changes due to changes in demand, i.e., adjustments in the number of vehicles that are sent to IROAN, is not at issue.

Deriving the benefits the Marine Corps receives for their investment in the IROAN process is the focus of this report. The traditional approach seeks to identify and quantify the amount of cost savings the Marine Corps is receiving from the program. The simplest way to do this would be to track what were the organizational and intermediate maintenance costs for a given set of vehicles with a known IROAN date. Analysis of this data over sufficient time and given a large enough sample size would likely prove adequate to substantiate the value of the IROAN program. Unfortunately, the Marine Corps supply and accounting systems are designed to meet the demands of the budgetary process. Thus they are designed to collect aggregate costs for units over the fiscal year. The Naval Center for Cost Analysis collects data from the Navy and Marine Corps and stores it in an online database named VAMOSC (Visibility and Management of Operations and Support Costs). This is a very useful and accessible database, but its utility is limited in this study by the fact that it does not track individual vehicle serial numbers in any way, and serial number is the only method available to determine when a vehicle has gone through the IROAN program.

Similarly, an analyst could measure the benefit received from the program in terms of increased operational readiness. The Marine Corps Integrated Maintenance Management System and the Marine Automated Readiness Evaluation System (MARES) are designed to report what vehicles are broken and the readiness of equipment. A useful

analytical endeavor would be to track the readiness of a sample of vehicles from one IROAN cycle to the next IROAN cycle. Again, because the focus of reporting systems is on readiness of the fleet of vehicles, rather than individual vehicles, the historical data on a particular vehicle is not accurate enough to be useful. Appendix A is a narrative of the life of a vehicle over a span of time and illustrates the difficulties of this approach.

B. DATA SOURCES & TECHNIQUE

Major Chris Frey USMC, and Mr. Bill Vinyard developed and have used a model to forecast the readiness of LAR units by the age of their vehicles. The goal of their model was to help them forecast the appropriate demand for IROAN to maintain a certain minimum level of readiness. In the model, vehicles are sorted into two pools; those that have been to IROAN within the past five years, and those that have not.

Frey and Vinyard fed normally reported data into their model. That is, the readiness of LAVs is reported weekly in an LM2 report from the Marine Automated Readiness Evaluation System (MARES). Readiness is reported by Marine Expeditionary Force. There are six different reporting units in this system for LAVs, I,II & III MEF, Marine Forces Reserve (4), Bases Posts and Stations(6), and Prepositioned Equipment(8). Based on weekly readiness reports over a six year period, Frey and Vinyard were able to generate the average readiness for the two IROAN categories, sorted by MEF.

C. LIMITATIONS AND ASSUMPTIONS

The resources available for any study are finite, and this one is no different. Time and labor considerations forced this study to use the data available. In this case, readiness reports from 1997 to 2003 were used to evaluate the effectiveness of the IROAN program. Although this data stops short of the major combat operations that have occurred since, it has the benefit of not being clouded by the turbulence generated from the frantic operational tempo over the past three years. Major combat operations have significantly altered the way the fleet has been managed out of necessity. Destroyed vehicles and frequent rotations of units have forced old patterns out of the way, and it is not clear what new cycle or pattern will work. In other words, the variability of the system over the past three years makes it difficult to assume many variables to be

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constant. The fact remains that the research data used is from a finite period that is not representative of the conditions placed upon the LAV fleet currently.

A second limitation concerns the number of variants studied. As this study highlighted in Chapter II, the variants are employed in different ways. However this study is focused on the 400 or so LAV-25s. There are two reasons for this limitation in scope. The first is that LAV-25's form the bulk of the population and are the principal weapon system of the units that have them. The second reason is that a large amount of data was reasonably available, making a more detailed examination of data possible. In other words, more time spent searching for data would have left less time analyzing the data for meaning. A more thorough examination including all of the variants is possible, given greater resources in terms of labor and/or time.

It is necessary to explicitly state the assumptions made to conduct this study. The Statement of Work (SOW) for the IROAN program has been reviewed and altered. It is a contract between the PM and the Depot over what work will be performed. Some method of normalization would be a preferred method for accounting for the changes in the SOW. This would require some kind of baseline understanding of the effectiveness of IROAN in one year. All other years could then be normalized from the base year. However since this is the first documented study of the effectiveness of IROAN, that baseline does not currently exist. For the purposes of this study, we must assume that an IROAN cycle in 1995 is equal in effectiveness to one in 2002, or all IROANs are equal.

D.   ALTERNATIVES TO BE EVALUATED

The stated current policy is to plan to send a vehicle to IROAN when it reaches one of three criteria; 6 years since last overhaul, 25,000 miles, or 2,000 operating hours. In reality, practice differs from policy and the default criterion is time since last IROAN. The PM wants measure of return the Marine Corps is receiving through its investment in IROAN. There are several potential methods to provide a meaningful answer to the PM's question. This research effort will analyze the comparative readiness effects of inputting LAVs into IROAN according to various time intervals. This project will compare the costs versus the readiness benefits associated with rotating vehicles into IROAN at intervals four, five, six, seven or eight years.

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IV. ANALYSIS

A. OVERALL FLEET

For the purposes of this paper, "fleet" will refer to the 407 LAV-25s in the Marine Corps inventory. "In Stores" means that a vehicle is either in the DMFA or the WRMR. "Out of Stores" refers to the number of vehicles that reside in one of the six Unit Identification Codes. Figure 10 represents total authorized inventory of 753 LAVs by variant.

Family of LAVs by variant

■	LAV-25
■	LAV-AT
◩	LAV-C2
▩	LAV-L
□	LAV-R
▨	LAV-M
▣	MEWWS

52   12
35
95
50
407
102

Numbers represent authorized quantities

Figure 10.   FOLAV variant population
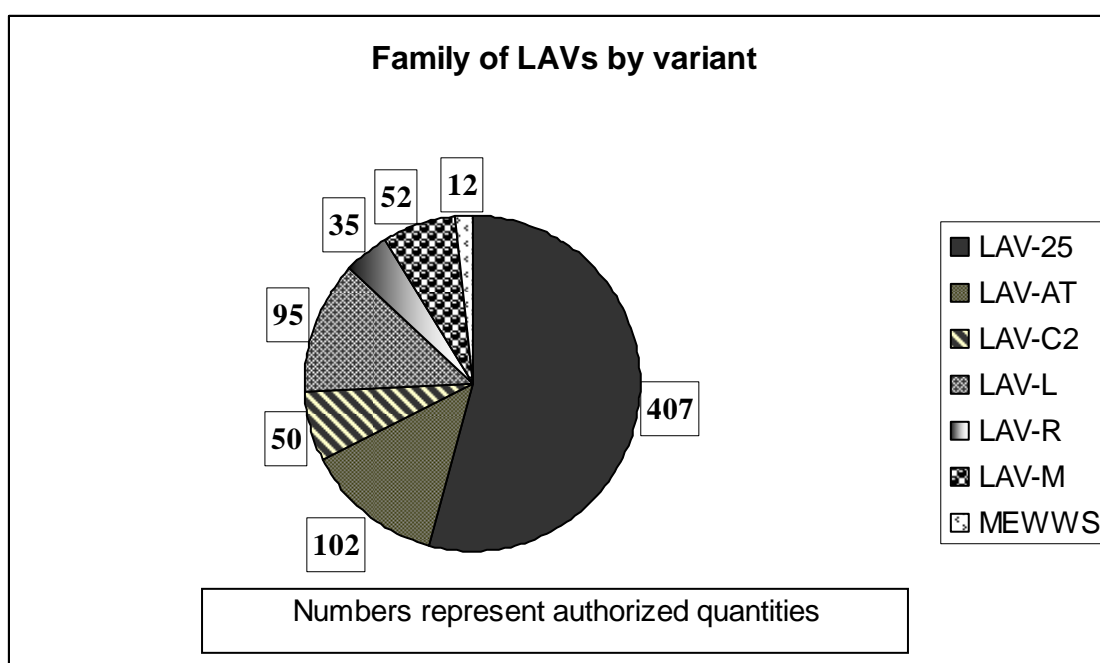
Figure 11 displays the distribution of the "Out of Stores" LAV-25 population by reporting unit, or UIC. This is a current picture of where LAV-25s are located. The data was accessed from the Marine Corps Equipment Readiness Information Tool (MERIT) in October 2006. It identifies the deployed vehicles, and highlights that the currently deployed vehicles were assigned to I MEF.
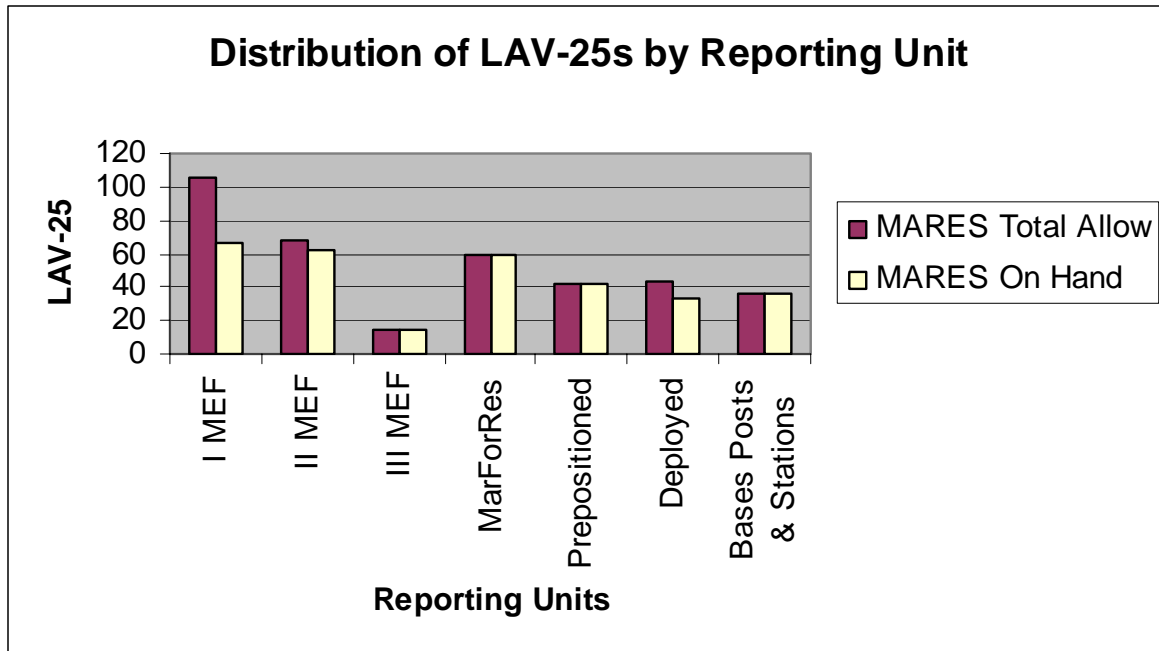
Figure 11. **LAV-25 Out of Stores Distribution as of October 2006.**

1. Statistics and Regression

Overall, the LAV-25s are being managed on an eight year cycle. The Frey model sorted the population into two baskets, IROAN within the past five years or not. The model was modified to use four, five, six, seven and eight years as the sorting condition. The model also sorted the data by MEF. This study altered the model to aggregate the reporting from all units. Given the total number of LAV-25s that have been through IROAN in the past 8 years and 7 years, we can find the population that has been through depot maintenance between 7 and 8 years. Repeating this process for 6-7 years, 5-6 years, and 4-5 years gives an average distribution of the "age" of the fleet with respect to IROAN. Table 1 and Figure 12 display the breakout, and show that despite the stated policy goal of six years, the fleet was actually being managed on an eight year cycle.

"AGE" Time since IROAN	R-Rating	Average Qty
< 4yrs	91.11%	186.35
4-5 Yrs	88.99%	50.96
5-6 yrs	88.30%	49.83
6-7 yrs	89.68%	50.41
7-8 yrs	89.68%	48.79

Table 1. **Fleet Readiness and Distribution by IROAN Age**

Distribution of LAV 25's by age

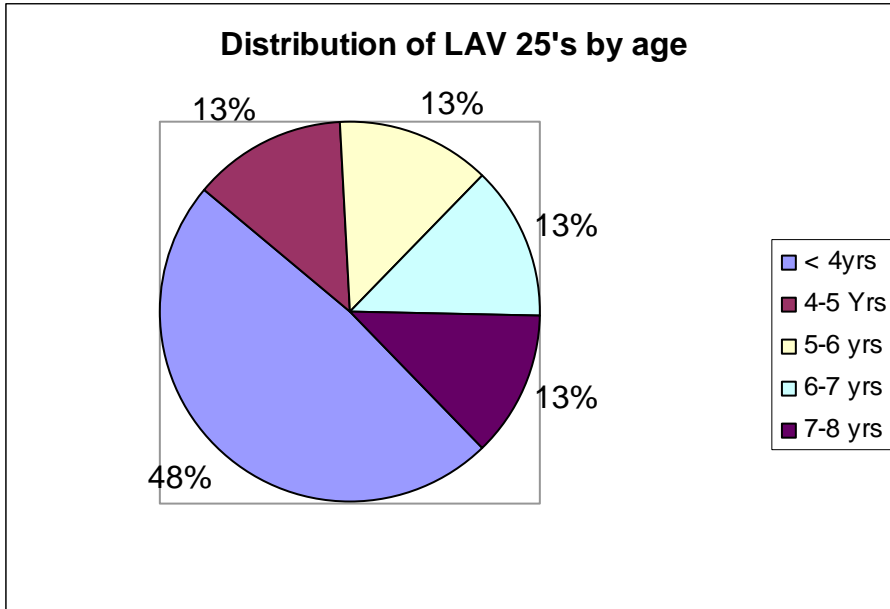**Figure 12.** **Distribution of LAV 25s by age since last Overhaul**

Figure 13 is a graphical representation of the readiness column in Table 1. This curve casts doubt on our hypothesis that Readiness should decrease as IROAN Age increases. The steady drop in readiness suddenly begins to improve past the six year point.
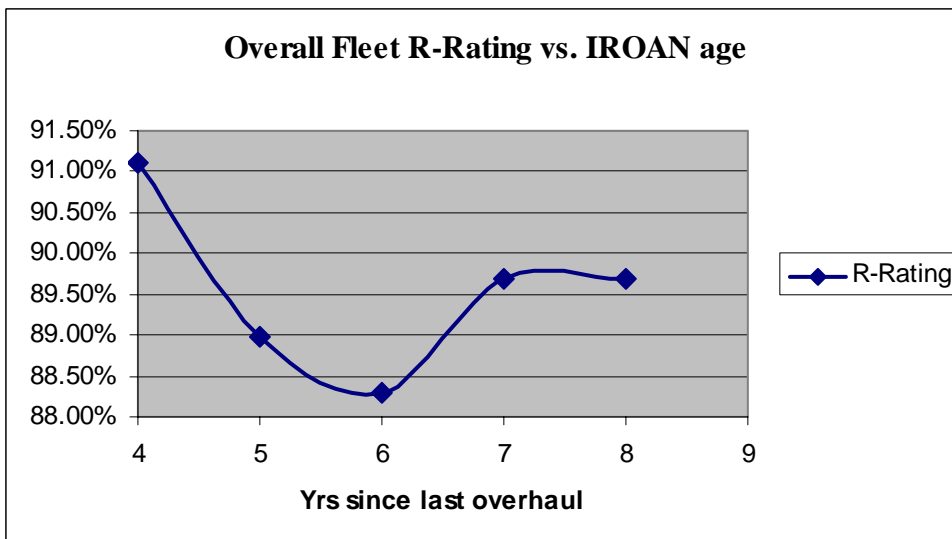
Overall Fleet R-Rating vs. IROAN age

Figure 13. **Overall Fleet Readiness against IROAN Age**

The author's experience with the vehicles combined with conversations with the Maintenance Officer from the Program Manager's Office led to some further assumptions. We believe that fleet management and employment conspire to mask the effect of IROAN on reported readiness.

2.   **Four Conditions Masking Effectiveness**

Four factors possibly serve to hide the effectiveness of the IROAN program. They are recognized by operators and maintainers within the community, but have not received systematic study.

One of these conditions could be termed the "Prepo Effect". On average, 13% of the LAV-25 fleet is on Maritime Prepositioned Squadrons. These vehicles are used only in training exercises and real world operations, which can generally be characterized as infrequent. Ownership of these vehicles shifts to the operating unit that signs for them, and subsequent readiness reporting will appear on their LM2 report, vice the LM2 report for prepositioned equipment.

Additionally, MPS squadrons are on a very lengthy rotation for their equipment to go through refit. Consequently, LAVs that are aboard MPS shipping are not routed through IROAN as frequently as operating force vehicles.

Likewise, the training pool in 29 Palms, California is a special case. The Exercise Equipment Allowance Pool (EEAP) has approximately one company's worth of vehicles on hand for a unit to fly in, draw these vehicles, conduct training, turn in the vehicles and fly home. These vehicles are used heavily, but because of the dry climate which severely limits corrosion and the intense maintenance scrutiny these vehicles receive, this population has not received a vehicle from IROAN in over 10 years (Persely phoncon of 4 October). Predictably, this skews the data by understating the effect of IROAN.

The third factor is what is called the "Hangar Queen". Operators recognize that some vehicles are more reliable than others regardless of crew maintenance efforts. Because of the flexibility in assigning which vehicle goes to IROAN, this "Hangar Queen" is likely to go to IROAN sooner than a normal vehicle.

The fourth consideration is vehicles within the Marine Forces Reserves. The Fourth LAR Battalion faces different challenges than the operating forces. This unit has less access to the supply system because of the distance involved. Reserve forces do not use their vehicles continually unless they are activated. And if they are activated, they would normally report their readiness under the reporting code of the MEF that they were assigned. The result is that the conditions underlying MFR readiness are significantly different from the active forces, and although time since last overhaul may be as significant for MFR as it is for the active forces, their overall readiness drivers are likely to be significantly different making the analysis less clear.

Three of these conditions can be factored out of the analysis, but the third one cannot. The "Prepo effect" and the "EEAP effect" and Reserve forces can be factored out of the analysis by removing their vehicles from the analyzed sample. The "Hangar Queen" effect cannot be factored out of the analysis, which means that subsequent calculations represent the lower bound for the effectiveness of IROAN. In other words, we will know that IROAN contributes at least this much to the operational readiness of the vehicle.

B.   OPERATING FORCES

Readiness reports from the active forces LM2 reports was analyzed in a similar manner to the overall fleet. The results were statistically significant. After removing non-operating forces from the data, the weekly population was sorted into two pools; DLM and non-DLM. The time since last IROAN, or "IROAN Age", is the discriminator for determining which pool the vehicle falls into for that weeks LM2 report. This sorting process was done for IROAN ages 1-8 years. The population for the 7-8 year group is calculated by subtracting the DLM population for year 7 from the DLM population for year 8. This process is repeated to generate the average weekly population in each IROAN age group. Figure 14 graphs the results. The standard deviation is included to give the reader a visual picture of the increasing variability.

Operating Forces LAV-25 Readiness against IROAN Age
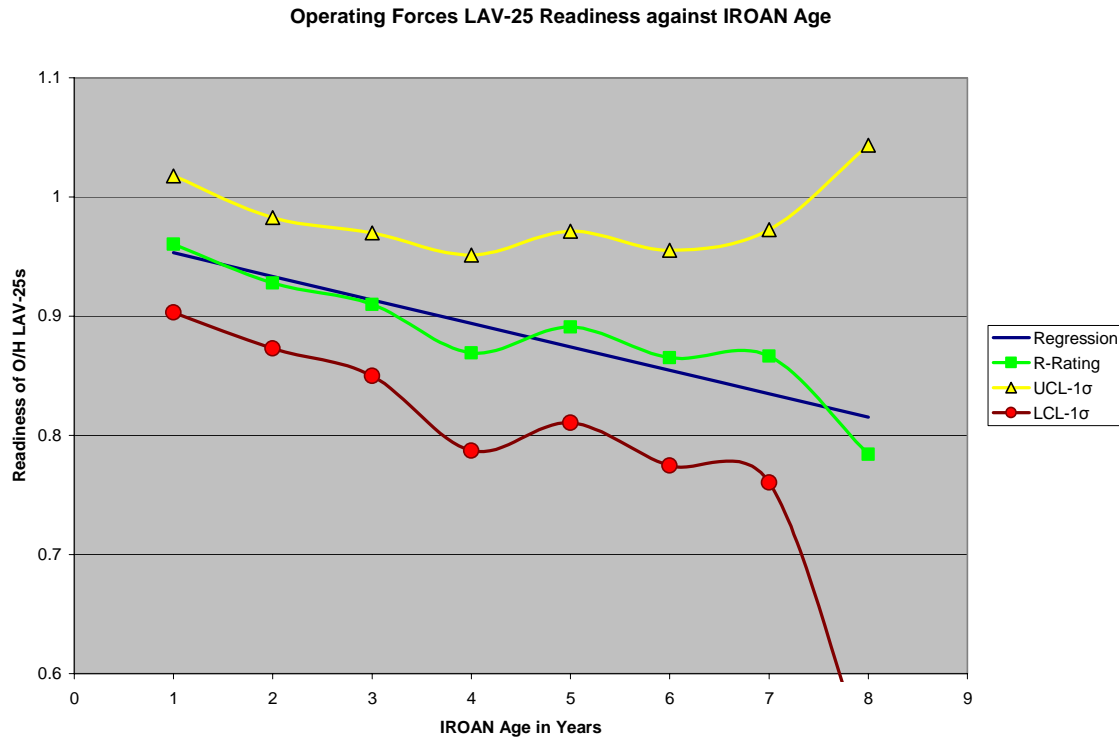
Figure 14. Operating Forces LAV 25 avg readiness against time since last overhaul

IROAN Age (Yrs)	R-Rating	+1σ	-1σ	Regression
1	96.04%	101.26%	90.82%	95.31%
2	92.77%	98.26%	87.28%	93.34%
3	90.98%	96.98%	84.97%	91.37%
4	86.91%	95.11%	78.72%	89.40%
5	89.09%	97.13%	81.06%	87.44%
6	86.50%	95.53%	77.47%	85.47%
7	86.63%	97.25%	76.02%	83.50%
8	78.42%	104.32%	52.51%	81.53%

Table 2. Table of Average Readiness of Operating Forces LAV-25s with Regression

There are several interesting characteristics of this data. First the regression is a pretty good fit to actual data. The actual adjusted coefficient of determination (Adj. R^2)

was 0.815. This means that age accounts for 81.5% of the variation of readiness by year from overall average readiness of Operating Forces LAV-25s.

Although this data is not perfect, it does represent a useful quantitative look at the effect of IROAN on the readiness of LAV-25s in the Operating Forces. We can use this data to conduct Step 3 of the Stokey & Zeckhauser framework; Predict Outcomes. However, some assumptions are necessary to predict these outcomes. One assumption is that the policy will be perfectly followed. For example, this means that if the prescribed policy is a 4 year cycle, then exactly one fourth of the vehicles will be in each age group. A second major assumption is that all other factors affecting readiness are held constant.

An explanation is required before discussion of the next assumption. We have the historical readiness of LAV-25s in a given IROAN age group. Given a particular policy, we simply divide the number of LAV-25s in the operating forces by age policy in years. The quotient is the number of vehicles in each year group. Multiplying year group populations by historical average readiness yields the expected number of vehicles that are operationally available for that year group. The sum across all year groups for that particular policy choice is the expected number of LAV-25s operationally available to the operating forces in theory.

The Depot Maintenance Float Allowance shields the operating forces from fully feeling the burden of the IROAN program. Because of the deleterious effects of current operations on this account, this research project has chosen to disregard the DMFA to get a clear picture of the cost of the IROAN program. So, in our calculation, we will subtract the cost of IROAN in equivalent vehicle terms from our expected operationally available LAV-25s. The calculation of cost is straightforward. The Table of Organization authorizes 180 LAV-25s for the Operating Forces. Divide this by the policy in years to get the annual IROAN requirement. Multiplying the annual IROAN requirement times the Repair Cycle Time in years yields the equivalent loss of LAV-25s. Figure 15 represents the results.
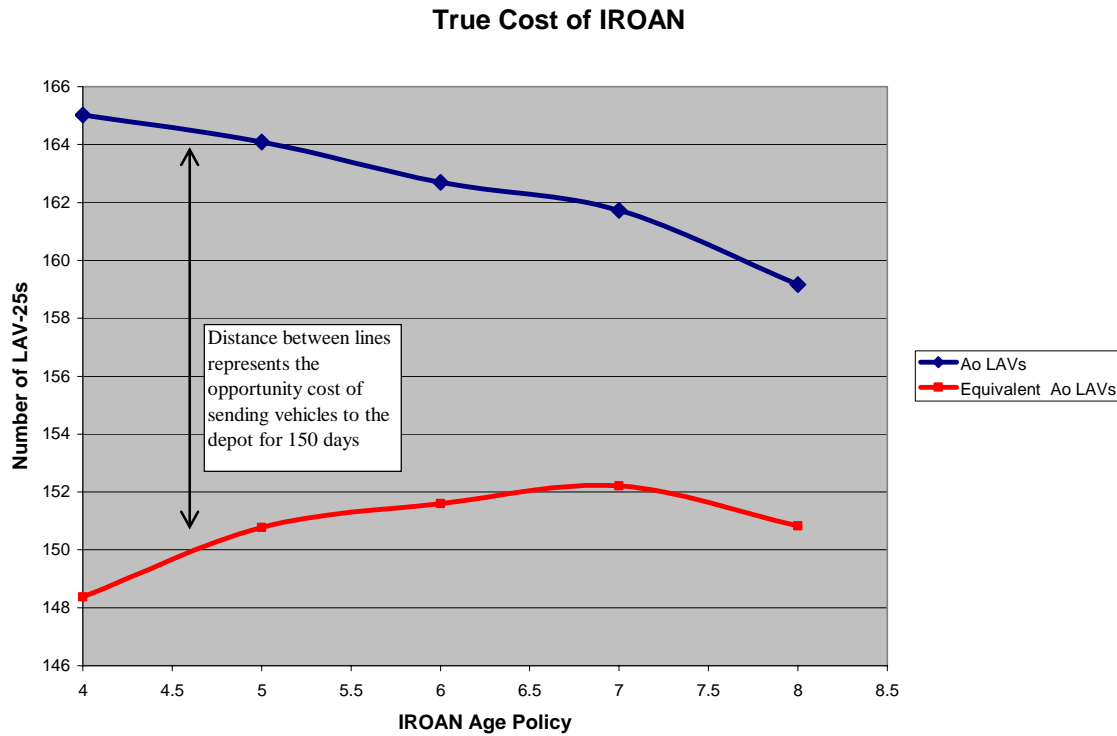
True Cost of IROAN

Figure 15.   True Cost of IROAN Program

Rotation Policy (Yrs)	E(R-Rating)	Program Cost	Expected Ao LAV-25s	Equivalent Ao LAV-25s
4	91.68%	$21,375,000	165	147
5	91.16%	$17,100,000	164	149
6	90.38%	$14,250,000	163	150
7	89.85%	$12,214,286	162	151
8	88.42%	$10,687,500	159	150

Table 3.   Table of Expected Operationally Available LAV-25s with IROAN Discount

Some equations with a sample calculation will help to clarify the table and graph. Table 4 below shows how the expected readiness rating was calculated. Note that this assumes the given rotation policy is being followed every year. There are 180 LAV-25s authorized to be held by active duty operating forces. Using the expected readiness for the Six Year Rotation Policy we can calculate the expected number of LAV-25s that would be operationally available. $180 LAV-25s * 90.38\% = 163 LAV-25s$

6 yr policy			
Yr group	Pct of inventory	Avg Readiness for Age	E(contribution)
1	0.17	96.04%	0.16006845
2	0.17	92.77%	0.154616498
3	0.17	90.98%	0.151629814
4	0.17	86.91%	0.144858331
5	0.17	89.09%	0.148491152
6	0.17	86.50%	0.144171258
7	0	86.63%	0
8	0	78.42%	0
	Expected Operating readiness from policy		**0.903835504**

Table 4.   Example of Expected Operating Readiness from Policy calculation

The opportunity cost is the cost of the IROAN rotation policy in terms of vehicles not available for operations. Under the Six Year Rotation Policy, 30 LAV-25s per year would be sent to IROAN (180 divided by 6 years). This study has used a RCT of 150 days or 0.41 years for this study.

$$30LAV - 25s/yr * 0.41yrs = 12.3LAV - 25s$$

On average, 12.3 LAV-25s will be at the depot when using the Six Year Rotation Policy. This opportunity cost is a further reduction in the number of LAV-25s available for employment on any given day, so we subtract this from the 163 vehicles that we expected to be available, giving an equivalent of 150 LAV-25s available for employment.

The implication is that a 7 year IROAN rotation policy is the most effective in maximizing the number of LAV-25s available for employment. This statement must be interpreted within the constraints of the data. The "Hangar Queen" effect is still present and it depresses the effectiveness of IROAN. So keeping in mind that this data represents the lower bound we modify this statement to say that the best IROAN policy is no more than 7 years, but could be more frequent. The expected benefits of implementing a seven year IROAN policy over the current six year policy is one additional LAV-25 operationally available and cost savings of $1.9 million (FY06) on average. The cost savings are generated through an average four vehicle reduction in demand of four vehicles with a unit cost of $475,000 per unit.

This research project purposely focused on measuring the economics effects of the IROAN program. Research into the efficiency of Depot Maintenance has been conducted in the past (Mullins 2005, Wilson 2001). Further study is warranted given the likelihood of non-value added activities in a process that is 150 days long. A sensitivity analysis serves to highlight the point. From Table 3, we see that under the 6-year policy we have 150 equivalent LAV-25s operationally available given a 150 day RCT for IROAN. A ten percent reduction is IROAN cycle time would reduce the opportunity cost of the program by two vehicles. That means two additional LAV-25s operationally available per day for the operating forces. In other words, reducing RCT 15 days is equivalent to improving the average readiness of the fleet by 1%. The SOAR program seeks to address this issue through a careful selection of activities for the depot to perform, but there are additional gains that can be made through the reduction of queues.

V.   CONCLUSIONS AND RECOMMENDATIONS

A.   CONCLUSIONS

The IROAN program generally has the anticipated positive effect on fleet readiness. As IROAN age increased, readiness decreased at around 2% per year. That is roughly an additional 7 days of dead-line for each LAV-25. This data helps put the IROAN program value in perspective, but does not answer the question of what is the value of IROAN. As previously stated, this research project will not value outcomes of the alternatives. The goal is to provide useful analysis to inform the Program Manager about potential outcomes from different policy choices. There are some other conclusions that can be drawn.

The actual rotation rate of the LAV-25 fleet is different than the stated policy. Overall, the LAV-25 fleet is being managed on an eight year cycle. The active duty operating forces are being rotated through IROAN very close to the stated policy of six years. This is expected and justified given the usage and importance of the active duty forces relative to other reporting units. Additionally, research indicates that a seven year rotation policy for active duty operating forces LAV-25s is better than the current policy if opportunity costs are considered. The expected marginal benefits of the seven year policy are a cost savings of $1.9 million FY06, and one additional LAV-25 operationally available.

The Frey model is useful for analyzing the effectiveness of any MARES reportable equipment in the inventory that has a regularly scheduled Depot Maintenance program. The data necessary to use this model for analyzing some other item in the Marine Corps inventory is obtainable with a modest amount of effort. The Readiness and Analysis Department within Marine Corps Logistics Command would be a reasonable place to start, as they have ready access to the necessary databases. Researchers seeking access to the database used by the author can contact the author, the lead advisor to this research project, the Maintenance Officer assigned to PM LAV, or the Readiness and Analysis Department at LOGCOM.

The information systems that store maintenance and supply data are either inadequate for focused studies, or difficult to use. The VAMOSC system stores a vast amount of information in a readily usable online database. But the data was not specific enough to be useful in this study. The MERIT database managed by LOGCOM had specific data, but it was not in a very usable form. To be fair, these databases are vast improvements over previous methods. But there are possible improvements to be made in the quantity and quality of data.

B. RECOMMENDATIONS

The stated policy is to take three variables into account; mileage, operating hours, and time. This study was only able to analyze one of the three variables. It would be beneficial to develop a multivariate statistical model to give a clearer picture of which of these variables has the greatest effect of readiness. At the time of writing, data of this quality would require enormous effort to collect because of the disjointedness of the Logistics Automated Information Systems of the Marine Corps. A serious effort has been put into replacing these legacy systems for many years. Hopefully the future system will store comprehensive maintenance and cost data with more specificity and in a more usable form.

This study could be part of a comprehensive analysis of the LAV Fleet's maintenance system. Further research is warranted into the relationship between readiness and parts availability, organizational and intermediate maintenance labor quantity and quality, and supply systems. This would provide a more complete picture of the system, and what results could be expected by changing each variable. Additional research into the readiness characteristics of other LAV variants would also be beneficial. As stated in the Chapter II, the operating conditions of each variant are different, placing different demands on the subsystems on the vehicle. It is reasonable to assume that the readiness profile of these variants might be quite different from the LAV-25. These efforts would give the Program Manager, and Marine Corps leaders, a better perspective on how to effectively manage available resources.

In the absence of a more comprehensive automated system, a detailed study of a set of an LAV sample over a finite period of time would also be a valuable undertaking.

Stewart Nickless (1998) conducted research into the operating cost drivers for the LAV fleet by focusing on I MEF. A similar effort, perhaps even more focused, could provide useful insight into what is the best IROAN policy.

This study was limited in scope to the IROAN program over a finite period with no major variations in fleet employment. The future of the LAV community will likely be quite different than the period considered. The current operational tempo is far greater than the period studied. The entire fleet of LAVs will be undergoing a major upgrade over the next three years. The SOAR Program is replacing the IROAN Program in the near future.

The IROAN program has been ongoing since 1994, and this is first documented attempt at assessing the program's contribution to Operational Availability. The potential benefits that this study uncovered could have been realized, had they been identified sooner. The major point is that analysis of the readiness benefits that any program creates is necessary when there may be more productive uses for those resources.

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APPENDIX: LIFE OF AN LAV-25

This appendix is a chronology of the life of one specific LAV-25, serial number 521611. There are two purposes for this appendix. One is to give the reader an idea of what the operating cycle is like for a vehicle. The other purpose is to give an indication of how many different sources are required to piece this history together. This particular vehicle was the author's while he was the company commander for Company B, Second Light Armored Reconnaissance Battalion from June 2003 until July 2004.

Maintenance history for LAVs can be accesses through MERIT. The data goes back to 1996. There are entries that date back to 1994, but they are not associated with particular reporting units. Theoretically, every corrective maintenance action and every scheduled second echelon Preventative Maintenance Check and Service is recorded in the system. The Equipment Repair Order (ERO) is comparable to a job order number, and it is recorded in the database as well. We can reconstruct the history of a vehicle by reviewing this record of transactions.

For example, the system does not record when a vehicle has gone to IROAN, since that program is separate from the normal maintenance process. But, since the database records the owning unit, we can scan the history for when there is a change in reporting units. This would likely indicate that an IROAN has occurred. If there were a long break between reported deficiencies this would tend to confirm our hypothesis, since the IROAN program is not brief.

A review of the maintenance history of 521611 reveals that from 1996 to 1999 the vehicle belonged to I MEF. The last ERO submitted by I MEF for this vehicle was in February 1999. The next entry was originated in II MEF in September 2000. II MEF reports on the vehicle until June 2005. I MEF reports the same discrepancy in July 2005 that II MEF reported in June. The author personally knows that the vehicle was switched during a unit rotation of deployed forces, which explains this phenomenon.

The depots keep the history of which vehicles have gone to IROAN when in their Serialized Tracking System (STS). Maintenance Center Albany's STS reports that

521611 entered IROAN in March 1999 and was issued to II MEF in August 2000, for a total of 17 months "in stores". This information meshes with the data that we pulled from our serial number query in MERIT.

The point is to illuminate the difficulties of tracking a vehicle's history. There is no single data source that currently provides information about the usage, maintenance, repair history, ownership, and depot rotation. MIMMS tracks the repairs made on vehicles as well as the parts and time required to effect repairs. The supply system, SASSY, records the cost of those repair parts. The Serialized Tracking System records when vehicles are passed through the depot, but not the cost of the actual overhaul. This is a shortfall that limits a program manager's ability to make decisions. The maintenance history of vehicles by serial number has been recorded. The quality of that information is questionable, it is not easy to compile, and it is difficult to analyze once compiled because of the format of the data. Quality information that is easily accessible begets quality decisions, and with the information as it is currently arrayed, gathering quality information requires significant resources. The current information systems are certainly an improvement over the past, but there remains plenty of room for improvement.

MEF	Priority	Defect Desc	Job Status Date	Job Status	Job Status Desc	Days D/L	Days In Shop	ERO/TASK
1	13	No Major Defect-SL-3 Application	4/11/2006	25	SHT PART		90	**WXG83**
1	03	Body, Frame, or Hull-Cracked, Broken, or Bent	4/7/2006	CL	CLOSED		140	**WXA42**
1	03	Body, Frame, or Hull-Cracked, Broken, or Bent	4/7/2006	CL	CLOSED		139	**Q7025**
1	03	Body, Frame, or Hull-Cracked, Broken, or Bent	3/10/2006	CL	CLOSED	73	20	**QUQ64**
1	06	Power Train-Cracked, Broken, or Bent	12/15/2005	CL	CLOSED		40	**WXA33**
1	06	Power Train-Housing and Castings	11/29/2005	CL	CLOSED		120	**WXA07**
1	06	Power Train-Cracked, Broken, or Bent	10/20/2005	CL	CLOSED		5	**Q7098**
1	06	Transmitter/Output Circuitry-Inoperative	10/20/2005	CL	CLOSED		77	**WXM22**
1	13	Body, Frame, or Hull-Replace	10/18/2005	CL	CLOSED		90	**WYC46**
1	13	No Major Defect-SL-3 Application	10/18/2005	CL	CLOSED		113	**WZC26**
1	06	Transmitter/Output Circuitry-Inoperative	10/4/2005	CL	CLOSED		70	**WYC52**
1	13	Body, Frame, or Hull-Replace	9/23/2005	CL	CLOSED		144	**WZC40**
1	06	Armament-Cracked, Broken, or Bent	8/22/2005	CL	CLOSED		37	**WYC32**
1	03	Turret System-Distribution Systems	8/19/2005	CL	CLOSED		29	**Q7046**
1	03	Turret System-Distribution Systems	8/19/2005	CL	CLOSED		21	**WXC22**
1	06	Armament-Cracked, Broken, or Bent	8/1/2005	CL	CLOSED		7	**WZC19**
1	06	Armament-Cracked, Broken, or Bent	7/28/2005	CL	CLOSED		28	**WYC16**
2	03	Body, Frame, or Hull-Housing and Castings	6/6/2005	CL	CLOSED	6	6	**QDA93**
2	06	Engine-Inoperative	1/20/2005	CL	CLOSED	3	16	**V3715**
2	02	LIGHT ARMORED VEHICLES	11/3/2004	JC	JOB COMPLETE	32	32	**F93VF36**
2	02	LIGHT ARMORED VEHICLES	11/3/2004	JC	JOB COMPLETE	34	34	**F93VE82**

Table 5. **Excerpt from MERIT Serial Number Query for 521611**

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